CUSTOMER NO.: 020991

03/29/00

JC780 U.S. PTO

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
APPLICATION TRANSMITTAL LETTER FOR
NONPROVISIONAL PATENT APPLICATION
Under 37 C.F.R. 1.53(b)

JC690 U.S. PTO 09/538080 03/29/00

Certification under 37 CFR 1.10 (if applicable)

EL370082614US
EXPRESS MAIL mailing number

March 29, 2000
Date of Deposit

I hereby certify that this application is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231.

Laura P. Aceves
(Type or printed name of person mailing application)

(Signature of person mailing application)

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Transmitted herewith for filing is the patent application, including 11 sheet(s) of formal drawings, of inventor(s):
Peter John Turley and Shih-Chang Wu

for: **SWITCH MATRIX FOR SATELLITE PAYLOADS WITH MULTIPLE UPLINK BEAMS AND ON-BOARD SIGNAL PROCESSING**

The filing fee for this application is calculated below:

		CLAIMS AS FILED		
	NUMBER FILED	NUMBER EXTRA	RATE	
Basic Fee				$690.00
Total Claims	12	-20= 0	x $ 18.00	$ .00
Independent Claims	3	- 3 = 0	x $ 78.00	$ .00
Multiple Dependent Claims			+ $260.00	$ .00
TOTAL FILING FEE :				$690.00

Please charge Deposit Account No. 50-0383 of Hughes Electronics Corporation, El Segundo, California, in the amount of **$690.00.** The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment, to that account.

The Commissioner is further hereby authorized to charge to said above Deposit Account No. 50-0383, pursuant to 37 CFR 1.25(b), any fees whatsoever which may properly become due or payable, as set forth in 37 CFR 1.16 to 1.17 inclusive, for the entire pendency of this application without specific additional authorization.

Please associate this application with the Hughes Electronics Corporation Customer Number 020991.
This form is submitted in triplicate.

HUGHES ELECTRONICS CORPORATION

Terje Gudmestad, Reg. 32,232

CUSTOMER NUMBER 020991
HUGHES ELECTRONICS CORPORATION
Patent Docket Administration
Bldg. 001, M/S A109
PO Box 956
El Segundo, CA 90245-0956
Telephone: (310) 662-8915

X Attorney or Agent of Record
_ Assignee of complete interest
_ Filed under 37 CFR 1.34(a)

09-506 (7/98)

SWITCH MATRIX FOR SATELLITE PAYLOADS WITH MULTIPLE
UPLINK BEAMS AND ON-BOARD SIGNAL PROCESSING

Inventors: Peter John Turley
Shih-Chang Wu

SWITCH MATRIX FOR SATELLITE PAYLOADS WITH MULTIPLE UPLINK BEAMS AND ON-BOARD SIGNAL PROCESSING

BACKGROUND OF THE INVENTION

5   1. Field of the Invention.

This invention relates in general to switch matrices, and in particular to a switch matrix for satellite payloads with multiple uplink beams and on-board signal processing.

2. Description of Related Art.

10   Communications satellites have become commonplace for use in many types of communications services, e.g., data transfer, voice communications, television spot beam coverage, and other data transfer applications. As such, satellites must provide signals to various geographic locations on the Earth's surface. As such, typical satellites use customized antenna designs to provide signal coverage for a particular country or

15   geographic area.

Many satellite payloads contain analog or digital signal processors. Analog processors are typically used to separate and combine different signals into specific channels ("channelize the signals"), and to switch different parts of the ground-to-satellite ("uplink") signal to different satellite-to-ground ("downlink") beams. Digital

20   processors are also used to channelize and switch signals, and may also be used to demodulate, process and remodulate signals. Usually these signal processors are heavy and consume a lot of DC power, so it is advantageous to be as efficient as possible in allocating processing resources to uplink beams.

Typically, the signals ("traffic") in each uplink beam to the satellite are different, since the population and economy in each uplink region is different. If the amount of traffic in each uplink beam is known before the satellite is launched, and does not vary over the life of the satellite, processing resources can be allocated to uplink beams with

5   fixed connections, which eliminates the need for the switch matrix. Typically, however, the amount of traffic in each uplink beam is either unknown beforehand or varies over time, and thus there must be some sort of switch matrix to reallocate and interconnect uplink beams to the on-board satellite processing resources.

Some traditional switch matrix designs, such as the crossbar switch or the Clos

10   switch matrix, were designed for use in telephone switching networks, and are designed for point-to-point connectivity. Other switch matrices have been designed for connections inside a computer or between networked computers. Some of these designs are not suitable for satellite signals at microwave frequencies, because the related art switch matrix designs suffer from isolation problems at microwave frequencies. Other

15   switch matrices do not provide for point-to-multipoint connectivity without excessive signal losses caused by power splitting. Many designs are also difficult to build out of smaller pieces in a modular manner.

It can be seen, then, that there is a need in the art for a switch matrix that is suitable for use in a spacecraft environment. It can also be seen that there is a need in

20   the art for a switch matrix that provides point-to-multipoint connectivity without excessive signal losses. It can also be seen that there is a need in the art for a switch matrix that provides ease of mechanical design and construction to reduce spacecraft costs.

SUMMARY OF THE INVENTION

To overcome the limitations in the prior art described above, and to overcome other limitations that will become apparent upon reading and understanding the present specification, the present invention discloses a method and apparatus for switching signals through a switch matrix. The apparatus comprises an input module and an output module. The input module has a plurality of inputs typically equal to a number of cells in a reuse pattern, and the inputs receiving at least one uplink beam. The input module also has a plurality of outputs, the plurality of outputs is typically equal to the number of subbands in the uplink beam. The output module is coupled to the input module and selectively couples the outputs from the input module to an output of the output module.

The method comprises the steps of grouping the uplink signals into a plurality of groups, the number of uplink signals typically equal to the number of cells in a cell-based transmission matrix and the number of groups typically equal to a number of cells in a reuse pattern in the cell-based transmission matrix, where each group comprises a signal from each frequency used in the frequency reuse pattern. Each group of uplink signals is then separated into subband signals, which are then grouped together into groups of similar subband signals. The groups of similar subband signals are then forwarded to demodulators for processing within the satellite system.

The present invention provides a switch matrix that is suitable for use in a spacecraft environment. The present invention also provides a switch matrix that provides point-to-multipoint connectivity without excessive signal losses. The present invention also provides a switch matrix that provides ease of mechanical design and construction to reduce spacecraft costs.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

FIG. 1 illustrates an exemplary block diagram of the uplink of a satellite with digital processing;

FIG. 2 illustrates the switch matrix of the present invention;

FIG. 3 illustrates the structure of the input switch modules of the present invention;

FIG. 4 illustrates an output switch module in accordance with the present invention;

FIG. 5 illustrates a switch matrix in accordance with the present invention that is used in dual-polarized uplink configurations;

FIG. 6 illustrates a switch matrix in accordance with the present invention that is used in dual-polarized uplink configurations with varying polarizations within an uplink beam;

FIG. 7 illustrates a switch matrix in accordance with the present invention that can use multiple polarizations simultaneously;

FIG. 8 illustrates a single input module with redundant input connections in accordance with the present invention;

FIG. 9 illustrates a specific example of a redundant input matrix of the present invention;

FIG. 10 illustrates a design that provides redundancy in the downconverters and in the input switch module of the present invention;

FIGS. 11 and 12 illustrate examples of failures within the configuration of FIG. 10;

FIG. 13 illustrates a complete design of a switch matrix of the present invention;

FIGS. 14A-14B illustrate the packaging of the present invention compared to the related art; and

FIG. 15 is a flow chart illustrating the steps used to practice the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following description of the preferred embodiment, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration a specific embodiment in which the invention may be practiced. It is to be

5   understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

Overview Of Related Art

Switch matrices are commonly used in many satellite telecommunications

10   systems designs to allow for redeployment of signals onboard the satellite. The switch matrix allows an input signal to be routed to any output desired through the use of crossbar switches or other types of switch matrices.

Some traditional switch matrix designs, such as the crossbar switch or the Clos switch matrix, were designed primarily for telephone switching networks, and are

15   designed for point-to-point connectivity. Other switch matrices were designed for connections inside a computer or between networked computers. Some of these designs are not suitable for microwave signals because of isolation problems, and other matrices do not provide for point-to-multipoint connectivity without excessive losses due to power splitting. Many designs are not easy to build out of smaller pieces in a modular

20   manner.

The present invention is suitable for microwave work, provides for point-to-multipoint connectivity with a greatly reduced amount of power splitting, and can be constructed from smaller pieces in a modular manner.

FIG. 1 illustrates an exemplary block diagram of the uplink of a satellite with digital processing.

The system 100 comprises an uplink antenna 102, downconverters 104, switch matrix 106, demodulators 108, and a digital signal processor (DSP) 110. Uplink antenna
5   102 receives a number of uplink beams 112, in this case 128 uplink beams 112, which are each fed to individual downconverters 104. Each downconverted uplink signal 114 is input to the switch matrix 106, which routes each signal to a given output of the switch matrix 106. The output signals 116 of the switch matrix are fed into demodulators 108, and then input to DSP 110 for processing. The DSP 110 has the capacity to service a
10   plurality of demodulators 108.

The system 100 is usually employed in a satellite telecommunications system that receives uplink information from transmitters on the ground. These transmitters are assigned in a "cellular" pattern, where each cell transmits information to the satellite within a given frequency band. Each cell within a frequency reuse group of cells uses a
15   different frequency band, and such groups are repeated throughout the cellular pattern to create a frequency-reuse pattern within the totality of cells in the system. Within each cell, the frequency band is divided into subbands. Each subband comprises individual signals from subscriber units, and each subband can contain zero or more signals.

For example, in FIG. 1, each demodulator 108 demodulates one of eight uplink
20   subbands. If the traffic is uniform, each uplink beam 112 will be allocated 2 demodulators 108, and each uplink beam 112 can carry ¼ of its maximum capacity. In such a case, each uplink beam 112 can be hardwired to two demodulators 108 directly

without using switch matrix 106, etc. until all 128 uplink beams 112 are connected to demodulators 108.

Typically, however, the traffic is not uniform, and each uplink beam 112 will carry a different amount of traffic, which makes switch matrix 106 a necessary part of system 100. Further, the traffic distribution changes during the lifetime of the satellite, possibly changing every hour or so. Switch matrix 106 is used to dynamically allocate demodulators 108 to uplink beams 112. In the example of FIG. 1, a switch matrix 106 with 128 inputs and 256 outputs is needed.

The most straightforward design for the switch matrix 106 of FIG. 1 is a crossbar switch in which every input 114 can be connected to any output 116 in any order, with each signal passing through one switch in the switch matrix 106. However, such a large crossbar switch matrix 106 would require 128*256 = 32,768 switches, and would be very difficult to manufacture in a modular manner from smaller switches.

The number of switches in switch matrix 106 can be somewhat reduced by using architectures like the Clos architecture, but the resulting matrix would still be difficult to manufacture in a modular manner. Crossbar and Clos design switch matrices 106 are not suitable for the system 100 of FIG. 1, either because they are not suitable for microwave switching networks due to isolation and connectivity problems, or because they cannot satisfy the point-to-multipoint requirements for system 100.

To broadcast one uplink signal 114 to multiple outputs 116, a power splitter is required inside of switch matrix 106. The more the uplink signal 114 is split, the greater the power loss through the switch matrix 106. In power limited applications such as spacecraft, it is vitally important to reduce this power loss as much as possible to reduce

the need for amplifiers within the system 100, to reduce both power consumption and weight on board the satellite.

For the switch matrix 106 described in FIG. 1, one uplink signal 114 must have the capability to be broadcast to 8 of the 256 outputs 116. This capability is typically

5   provided by using a 1:256 power divider, followed by a switching network, within switch matrix 106. For satellite applications, this approach leads to unacceptably high losses within the switch matrix 106.

However, switch matrices 106 of the related art were not optimized to take into account how system 100 is typically implemented. First, satellite payloads with multiple

10   uplink beams 112 typically use a frequency reuse scheme such as 4-cell or 7-cell frequency reuse. Adjacent cells within the frequency reuse scheme cannot use the same frequency and, therefore, cannot use the same subbands. This reduces the connectivity requirements of the switch matrix 106, as described herein with respect to the present invention. Second, the demodulators 108 may often be grouped by subband, e.g., some

15   demodulators 108 demodulate only the first subband, other demodulators 108 only the second subband, etc. One input signal 114 must have the capability to be broadcast to all of the different subband demodulator 108 types, but one input signal 114 does not have to be broadcast to more than one demodulator 108 in a given group of demodulators. As such, the switch matrix of the present invention is further reduced in

20   complexity while still providing the interconnections required for system 100.

Overview Of The Invention

        The invention allows for a flexible allocation of processing resources to uplink

beams for satellite payloads with on-board processing, which allows the processor

resources to be used more efficiently. This reduction on the complexity of the switch

matrix reduces the weight and power required by the processor to accomplish the

5   mission goal. The present invention is simpler than comparable switch matrices and can

be constructed from simpler switches allowing it to be used for satellite payloads. The

amount of power splitting inside the switch matrix of the present invention is reduced, so

it has a lower loss and a lower noise figure than other related art designs.

10   This invention applies to all satellites with digital or analog processing of signals

that divide multiple uplink signals into several subbands. It is most useful when the

uplink traffic distribution varies over time or is not well known before launch.

        FIG. 2 illustrates the switch matrix of the present invention. A satellite using

switch matrix 200 of the present invention uses multiple uplink beams 114 that use c-cell

15   frequency reuse, where c is the number of cells in the reuse pattern. Input signals 202A

are therefore input to input switch module 204A, and input signals 202A comprise c

uplink beams, which equals one entire reuse pattern. C is typically equal to 3, 4, 7, 9, or

12, but can be other numbers. N is the number of reuse patterns on the ground. As

such, the total number of uplink beams 114 is c times n (c*n). To accommodate the

20   entire complement of uplink beams 114, n input switch modules 204A-204N are used to

receive all of the c*n uplink beams 114.

        The uplink signals 114 are mulitcarrier, and to accomplish the demodulation, the

uplink signal 114 is divided into d subbands. Therefore, each input switch module 204A-

204N must provide d outputs. The output switch modules 206A-206D must accept one input from each input switch module 204A-204N, and therefore have n inputs. A demodulator 108 can demodulate one of these d subbands, and m demodulators are devoted to each subband. The total number of demodulators 108 is therefore d*m, and

5   each output switch module 206A-206D must provide m output signals. Therefore, each output switch module is an n*m matrix.

Switch matrix 200 of the present invention comprises n input switch modules 204A-204N, and d output switch modules 206A-206D. Each of the inputs 202A to the input switch module 204A comes from a single uplink reuse group, so that none of the

10   inputs 202A can share an uplink frequency. The switch matrix 200 of the present invention thus has a c*m input capability, and a d*m output capability, which provides proper interconnectivity for the system 100 without excess weight or power consumption.

15   Input Switch Modules

FIG. 3 illustrates the structure of the input switch modules of the present invention. Each input switch module 204A-204N receives inputs 202A-202N. For clarity, input switch module 204A is shown as a typical design. Signals 202A, which comprise signals 300 and 302, are fed into a plurality, i.e., "c" 1-to-d power splitters

20   304A-304C. Each power splitter 304A-304C takes a single input signal, e.g., 300, and produces a plurality of substantially equivalent power outputs from signal 300, e.g., 306A-306D. For example, if power splitter 304A was a 1:4 power splitter, and a 100 microwatt (μW) input signal 300 was fed into power splitter 304A, then power splitter

304A would produce four output signals 306A-306D, each approximately a 25 μW signal. There would be some losses through power splitter 306A, which would reduce the 25mW output power of each signal by some percentage amount. In the related art, a similar input signal would be split 256 times, making each output signal less than 1μW,

5   which may be difficult to process without amplification.

Each output 306A-306D from each power splitter 304A-304C is fed into a c:1 switch 308A-308D. Since each switch 308A-308D produces only one output 310A-310D, there are d switches 308A-308D in each module 204.

10   Output Switch Modules

FIG. 4 illustrates an exemplary output switch module in accordance with the present invention. Output switch module 206A, shown as a typical output switch module 206, is a concentrator, e.g., output switch module 206A receives the n input signals 310 from the input modules 204 and allows only m of the n input signals 310 to

15   be output signals 116 from output switch module 206A. Every output 116 of an output switch module 206A is connected to a demodulator 108 that demodulates one of the d subbands. Since each output 116 is identical, the output switch module 206A does not have to be fully connected as in the related art, but the output switch module 206A should ensure that in any arrangement of inputs 310, the subset of inputs 310 must be

20   switchable to an output 116. Since each group of c cells cannot use more than d demodulators, m, which is the number of demodulators of one type, must be less than or equal to n, the number of frequency reuse groups.

The complexity of the output switch modules 206 may vary greatly with n and m. For example, if m = n, then the output switch modules 206 become straight connections from input 310 to output 116 with no switching required. However, If n is the square of a number, it is possible to build the output module from simpler submodules. As an example shown in FIG. 4, if input signals 310 number 64 and the output signals 116 number 32, it is possible to build the output switch module 206 using eight 8 × 8 input submodules 400A-400H and eight 8 × 4 output submodules 402A-402H. Since all of the outputs of the output module 206 are identical, the output module does not have to be fully connected, which allows the present invention to implement a switching scheme that is simpler than a crossbar architecture for the output module 206. However, the output switch module 206A as shown is fully connected, which allows for any traffic pattern on the ground that is supported by frequency reuse rules and by the capacity of the processor to be supported by the output switch module 206. This way, if the traffic distribution changes during the life of the satellite, the switch matrix can be reconfigured to support the new traffic distribution.

Constructing the output switch matrix 206 out of simpler submodules 400 and 402 makes it easier to manufacture and test the design of the present invention over that of a full crossbar switch. Modules can be produced and tested separately from the rest, and the production of numerous identical modules can make product design easier.

In the discussion above, it is assumed that the outputs of each output submodule 402A-402H are connected to different types of demodulators with each type demodulating a different subband. The output switch module 206, however, can be used

with any payload that has multiple uplink beams with frequency reuse and has some sort of processing, analog or digital, that splits the uplink band into several subbands.

Alternative Embodiments of the Present Invention

5   FIG. 5 illustrates a switch matrix in accordance with the present invention that is used in dual-polarized uplink configurations. Satellite systems often use a dual polarized uplink, with some signals transmitted up with right-hand circularly polarized (RHCP) carriers with the others using left-hand circularly polarized (LHCP) carriers. In some systems, users in a particular uplink beam are constrained to use only one polarization, so

10   that half of the uplink beams use RHCP and the other half of the uplink beams use LHCP.

          As shown in FIG. 5, system 500 divides the uplink beams 114 in half. One-half of the uplink beams 114 in a reuse group will be LHCP, and are grouped in one input module 502A, while the other input beams are RHCP and are grouped in a separate

15   input module 502B. The resultant system 500 has twice the number of input modules 502A-502B as system 200, but each input module 502A-502B has one-half the number of inputs as input modules 204A-204N.

          Since both polarizations are used in system 500, the maximum capacity of the spacecraft is doubled which means twice the number of demodulators 108 can be

20   employed by the spacecraft. As such, m, the number of demodulators, may be as large as 2n, the number of reuse patterns on the ground, since every reuse pattern may use both polarizations. Therefore, the output switch modules 504A-504B should contain inputs numbering 2n, and outputs numbering m.

FIG. 5 illustrates the case where the number of uplink beams 114 is even. However, the number of uplink beams 114 can be an odd number, thereby making exact division by two impossible. If the number of uplink beams 114 is an odd number, the $c/2$ input beams 506 number $(c+1)/2$, and the number of inputs 508 to the output

5   switch modules 504A-504B number $2c*n/(c+1)$.

FIG. 6 illustrates a switch matrix in accordance with the present invention that is used in dual-polarized uplink configurations with varying polarizations within an uplink beam. As discuss with respect to FIG. 5, some satellite systems use polarized uplink beams. FIG. 5 illustrated the scenario that described users in a particular uplink beam

10   that are constrained to use only one polarization. The scenario of FIG. 5 was limited to a fixed polarization for each uplink beam, but this polarization may change over the life of the satellite. FIG. 6 illustrates a switch matrix that can be used in such a scenario.

System 600 utilizes an input signal 114 from every cell c in the reuse group, but doubles the number of outputs from each input switch module 602A-602N to twice the

15   number of bandwidths, i.e., 2d. To accommodate the increased number of outputs from input switch modules 602A-602N, the number of inputs 604 to each output switch module 606A-606D is increased to twice the number of the reuse patterns on the ground, or 2n. As with FIG. 5, since both polarizations are used, the maximum capacity of the spacecraft is doubled, so that the number of demodulators 108, or m, can be as

20   large as 2n. However, in system 600, each input switch module 602 has two outputs 608A-608D that are coupled to an output switch module 606A-606D, e.g., input switch module 602A has two outputs 608A coupled to inputs 604 numbers 1 and 2 on output switch module 606A. System 600 can also be used to provide redundancy within the

system, for example, if output 1 of input switch module 602A were to fail, output 2 can still connect input switch module 602A to output switch module 606A.

FIG. 7 illustrates a switch matrix in accordance with the present invention that can use multiple polarizations simultaneously. System 700 illustrates a system that uses

5   an uplink antenna with two output ports per beam, one for each polarization. This use of two output ports doubles the number of antenna outputs, which doubles the number of inputs 114 to the number of inputs to the switch matrix 700. The number of input switch modules 702A-702N has doubled to 2n, one input switch module 702A-702N for each cell group. As with FIGS. 5 and 6, the maximum capacity of the spacecraft is

10   doubled since both polarizations are used, and therefore, the number of demodulators may be as large as twice the number of cell patterns on the ground, which forces the number of inputs to the output switch modules 704A-704D to be 2n and the number of outputs to be m, where m may be as large as 2n.

15   Redundancy Designs

The designs of FIGS. 2-7 are all somewhat vulnerable to single point failures. However, redundancy can be designed into a switch matrix of the present invention to avoid single point failures within the spacecraft. For example, if a switch on an output port of an output module 206A fails, the demodulator 108 that follows the switch is no

20   longer useable, because the demodulator 108 will no longer receive an input. For this reason, additional demodulators 108 in each subband can be installed to allow a signal to be rerouted through the switch matrix of the present invention for that subband.

The present invention can also have redundancy built in to avoid single point failures within the matrix itself. For example, referrring to FIG. 2, there are n*d interconnections between the input switch modules 204A-204N and the output switch modules 206A-206D. Since there are only m*d outputs 116, and m<n, some of the

5   interconnections between input switch modules 204A-204N and output switch modules 206A-206D have no usable signals going through them. If some of the switches are lost on either side of these interconnections, which would render those switches unusable, the impact to the system is typically not very large.

On the other hand, the loss of an input port to the switch matrix is very serious.

10   Referring again to FIG. 2, if one of the input ports receiving uplink beams 114 is not useable, the uplink beam 114 connected to that port is also unusable. This leads to a hole in the coverage of the satellite where terminals can not uplink to the satellite. Although the input port is connected to a 1:c power splitter, and this passive device typically does not fail nearly as much as an active switch, the small chance of failure is

15   often unacceptable. In these cases, the input module can be redesigned to make it more redundant.

FIG. 8 illustrates a single input module with redundant input connections in accordance with the present invention.

Typically, the input to the switch matrix includes a downconverter 104 as shown

20   in FIG. 1. The input redundancy for the switch matrix can be combined with the downconverter 104 redundancy. For example, uplink cells 112, instead of being input directly into downconverters 104, are input to a redundancy matrix 800. Redundancy matrix can be used to supply any level of redundancy, but for ease of explanation, a c+1

for c redundancy is described herein. For example, since there are c cells in a reuse
group, one additional output is provided from each redundancy matrix 800 to prevent a
failure of an input port on input switch module 204A from being a single point failure
for a given uplink beam 112. This provides inputs 802A to 802N to input switch module

5   204A, which is now a (c+1) x d matrix. It can be seen that additional redundancy or
alternative redundancy schemes can be provided by making redundancy matrix 800 a
c+n for c matrix, and input switch module a (c+n) x d matrix.

FIG. 9 illustrates another example of a redundant input matrix of the present
invention, related to the embodiment of FIG. 5. Input beams 112 for a four cell reuse

10 system having a fixed polarization per cell will use 4 inputs to redundancy matrix 801,
which provides an eight-for-seven redundancy. Redundancy matrix 801 will produce
eight outputs for a single polarization, namely 802A through 802H. Each output 802A
through 802H is provided to input switch module 204A, and modules 304A through
304D respectively. There are a total of eight subbands, and therefore modules 304A

15 through 304D produce 8 outputs. The downconverter 104 redundancy is 8 for 7 as are
the inputs to input switch module 204A.

Redundancy matrix 800 also provides redundancy for each uplink beam 112. If
an input to input switch module 204A fails, for example input 802A, uplink beam 112
number 1 can be rerouted to input 802B, which can then switch uplink beam 112

20 number 1 through input switch module 204A and module 304A. This is done by using
hybrid 900 and hybrid 902, which can route the uplink beam 112 to either input 802A or
802B. Similar results can be achieved for all of the uplink beams 112.

Depending on how the downconverters 104 are configured, the signal from uplink beam 112 number 3 can be paired with the signal from uplink beam 112 number 2 or the signal from uplink beam number 4. Therefore, uplink beams 112 2, 3, and 4 should all have the same polarization assignment, and uplink beam 112 number 3 should

5   originate from a cell that cannot share frequencies with uplink beam number 2 or uplink beam 112 number 4. Preferably, all of the uplink beams 112 assigned to the redundancy matrix 800 should have the same polarization assignments, and uplink beams 112 assigned to adjacent inputs should originate from cells that cannot share frequencies because they are in the same cell frequency reuse pattern.

10   While the design in FIG. 9 provides some redundancy in the downconverters 104 and input switch module 204A inputs, the design of FIG. 9 does not allow for two downconverters 104 in a single redundancy matrix 800 to fail, nor does it provide provide any redundancy for the input modules 304A-304D of the input switch module 204A.

15   FIG. 10 illustrates a design that provides redundancy in the downconverters and in the input switch module of the present invention.

System 1000 comprises two redundancy matrices 800. Within each redundancy matrix 800, each uplink beam 112 is input to a hybrid power splitter 900, which has outputs to two different downconverters 104. This configuration makes downconverters

20   104 fully 2 for 1 redundant, so that more than one downconverter can fail in a single redundancy matrix 800.

Each uplink beam 112 is also sent to two different power splitter modules 304A-304H within input switch module 204A. For example the primary output for uplink beam 112 1002 is sent to an input on module 304A, while the redundant output for uplink beam 112 1004 is sent to an input on a different module 304B. With the

5   configuration of FIG. 10, the input switch module 204A can survive the failure of 1 input module 304A-304H. As with FIG. 9, uplink beams 112 should be paired such that adjacent inputs should come from cells that have the same polarization assignment and are within the cell frequency reuse pattern.

FIGS. 11 and 12 illustrate examples of failures within the configuration of FIG.

10   10. As shown in FIG. 11, the downconverter 104P, the primary downconverter 104 for uplink beam 112 number 11 has failed. The spacecraft, either through autonomous operation, monitoring of the downconverter 104P, or manual intervention, can switch to redundant downconverter 104R. Input 1100 to module 304G will no longer receive inputs from downconverter 104P. However, uplink beam 112 number 11 can still be

15   switched through input switch module 204A through input 1102 to module 304F. Other uplink beams 112 may also have to be switched through the input switch module 204A to prevent interference. For example, uplink beam 112 number 9 is typically not within a four cell reuse pattern with uplink beam 112 number 11, so uplink beam 112 number 9 is also switched to the redundant downconverter 104R associated with uplink beam 112

20   number 9. Input 1104 no longer receives input from uplink beam 112 number 9, which is switched through input switch module 204A through input 1105 on module 304E, and is paired with uplink beam 112 number 8. If the traffic density is low and if there is no need for uplink beam 112 number 9 to use the same subband as uplink beam 112

number 11, uplink beam 112 number 9 can continue on input 1104 through primary downconverter 104P until primary downconverter 104P fails, or the traffic in the region becomes heavy enough that uplink beam 112 number 9 and uplink beam 112 number 11 must use the same subband.

FIG. 12 illustrates an example where a module 304 in input switch module 204A fails. If module 304B fails, all of the inputs to module 304B become unusable by input switch module 204A. The primary inputs 1200 and 1202 are associated with uplink beam 112 number 3 and uplink beam 112 number 4, which must be switched to redundant inputs 1204 and 1206, respectively.

Other switching may have to take place within input switch module 204A to maintain correct uplink beam 112 pairings. For example, uplink beams 112 numbers 5, 6, and 7 may also require switching to inputs 1208-1212 respectively to maintain proper pairing or traffic density. If the traffic density is low enough, some of the uplink beams 112 numbers 5, 6, and 7 may be kept with the associated primary downconverter 104, but whenever there are three active inputs on a single module 304 the ability of the payload to concentrate capacity on the associated cells may be impaired.

FIG. 13 illustrates a complete design of a switch matrix of the present invention. For a four-cell reuse pattern with two polarizations, where each cell uses only one of the polarizations, the system 1300 of FIG. 13 can be employed. The design uses a total of 112 uplink cells, so there are 112 uplink beams 112 going into the downconverters 104. The downconverters 104 are 2 for 1 redundant, and the primary and redundant downconverters 104 have separate connections to the switch matrix, for a total of 224 connections. The input modules 304 have four inputs and eight outputs, and are

connected to the downconverters 104 as shown in FIG. 10. The uplink bandwidth is broken into eight subbands, so there are eight different types of demodulators 108. There are thirty-two demodulators 108 used for each subband, although a smaller number, for example twenty-eight demodulators 108, are typically needed to meet

5   capacity specifications. The extra four demodulators 108 in each subband can be used for redundancy.

Packaging

FIGS. 14A-14B illustrate the packaging of the present invention compared to the

10   related art.

FIG. 14A illustrates a packaging scheme for the switch matrix of the present invention. Switch matrix 1400 consists of an input matrix 1402, an interface plate 1404, and an output matrix 1406. The input matrix has a number of "slices" 1408, each containing input modules 1410. Output matrix 1406 contains interconnect matrices

15   1412 and output modules 1414, and consists of a plurality of "slices" each containing interconnect matrices 1412 and output modules 1414. The input modules 1410 are connected to interconnect matrices 1412 through the interface plate 1404. As such, there are a large number of signals that must pass through interface plate 1404 to connect input modules 1410 to interconnect matrices 1412 properly.

20   FIG. 14B illustrates an alternative packaging design illustrating a simpler packaging design for switch matrix 1416 of the present invention. Switch matrix 1416 comprises input modules 1408 directly coupled to output modules 1414, without the need for interface plate 1404 or interconnect matrices 1412. This reduces the signal

density, and therefore the complexity of switch matrix 1416, making switch matrix 1416 of the present invention easier to manufacture, test, and integrate into the spacecraft. However, switch matrix 1416 is not a fully connected matrix as the packaging design of FIG. 14A is. The switch matrix 1416 is thus less capable of in-flight redistribution of

5   signals, because the beams are grouped into specific sections, and cannot be switched between one section and another. However, many applications may not require a fully connected matrix, and therefore, the packaging of FIG. 14B can be used to simplify the manufacture, testing, and integration of switch matrix 1416 into the spacecraft.

10   Process Chart

FIG. 15 is a flow chart illustrating the steps used to practice the present invention.

Block 1500 illustrates performing the step of grouping the uplink signals into a plurality of groups, the number of groups at least equal to a number of cells in the cell-

15   based transmission matrix, each group comprising a signal from each frequency used in the frequency reuse pattern.

Block 1502 illustrates performing the step of separating each group of uplink signals into subband signals.

Block 1504 illustrates performing the step of grouping similar subband signals

20   from the groups of uplink signals to produce groups of similar subband signals.

Block 1506 illustrates performing the step of forwarding the groups of similar subband signals to demodulators for processing within the satellite system.

Conclusion

This concludes the description of the preferred embodiment of the invention. The following paragraphs describe some alternative methods of accomplishing the same objects. The present invention, although described with respect to RF and electrical

5 systems, can also be used with optical systems to accomplish the same goals. Further, the switches in the switch matrix can be actual switches, or hybrid electronics, or other switching mechanisms that perform similar functions.

In summary, the present invention discloses a method and apparatus for switching signals through a switch matrix. The apparatus comprises an input module and an output

10 module. The input module has a plurality of inputs typically equal to a number of cells in a reuse pattern, and the inputs receiving at least one uplink beam. The input module also has a plurality of outputs, the plurality of outputs is typically equal to the number of subbands in the uplink beam. The output module is coupled to the input module and selectively couples the outputs from the input module to an output of the output module.

15 The method comprises the steps of grouping the uplink signals into a plurality of groups, the number of groups typically equal to a number of cells in the cell-based transmission matrix, where each group comprises a signal from each frequency used in the frequency reuse pattern. Each group of uplink signals is then separated into subband signals, which are then grouped together into groups of similar subband signals. The

20 groups of similar subband signals are then forwarded to demodulators for processing within the satellite system.

The foregoing description of the preferred embodiment of the invention has been presented for the purposes of illustration and description. It is not intended to be

exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.

CLAIMS

<u>What is Claimed Is</u>:

1   1.   A switch matrix for coupling an uplink beam to a demodulator, comprising:

2   an input module, the input module having a plurality of inputs at least equal to a

3   number of cells in a reuse pattern, the inputs receiving at least one uplink beam, and a

4   plurality of outputs, the plurality of outputs at least equal to a number of subbands in the

5   uplink beam; and

6   an output module, the output module coupled to the input module, for selectively

7   coupling the outputs from the input module to an output of the output module, the output

8   of the output module coupled to a demodulator thereto.

1   2.   The switch matrix of Claim 1, wherein the output module is directly

2   coupled to the input module.

1   3.   The switch matrix of Claim 1, wherein the input module comprises

2   redundant modules.

1   4.   The switch matrix of Claim 1, wherein the input module accepts uplink

2   beams of different polarizations.

1   5.   The switch matrix of Claim 4, wherein the input module accepts uplink

2   beams of a single polarization.

1   6.   A switch matrix for coupling an uplink beam to a demodulator in a satellite

2 system, wherein the satellite system receives input from cells in a cell pattern, comprising:

3   (a) a plurality of input modules, each having a plurality of inputs at least equal to a

4 number of cells in a reuse pattern for the satellite system, each input module comprising:

5   (1) a plurality of power splitters, wherein the plurality of power splitters is at

6 least equal to the number of cells in the reuse pattern for the satellite system, wherein each

7 power splitter splits each input into a plurality of substantially equal power outputs, a

8 number of power outputs at least equal to a number of subbands used by the satellite

9 system; and

10   (2) a plurality of switch modules, coupled to the plurality of power splitters,

11 each switch module accepting a plurality of inputs at least equal to the number of cells in

12 the reuse pattern for the satellite system, the plurality of switch modules at least equal to the

13 number of subbands used by the satellite system; and

14   (b) a plurality of output modules, coupled to the input modules through the

15 plurality of the switch modules, each having a plurality of inputs at least equal to the

16 number of cells in the cell pattern, comprising:

17   (1) a first set of output matrices, each output matrix in the first set of

18 output matrices having a plurality of inputs at least equal to the number of subbands used

19 by the satellite system; and

20   (2) a second set of output matrices, coupled to the first set of output

21   matrices, each output matrix in the second set of output matrices having a plurality of

22   outputs at least equal to a number of demodulators used by the satellite system in each

23   subband.

1   7.   The switch matrix of Claim 6, wherein each output module is directly

2   coupled to the input modules.

1   8.   The switch matrix of Claim 6, wherein the input modules comprise

2   redundant modules.

1   9.   The switch matrix of Claim 6, wherein the input modules accept uplink

2   beams of different polarizations.

1   10.   The switch matrix of Claim 6, wherein the input modules accept uplink

2   beams of a single polarization.

1   11.   A method for switching uplink signals through a switch matrix in a satellite

2   system, the uplink signal generated by a cell-based transmission matrix, wherein a frequency

3   reuse pattern is used throughout the cell matrix and the uplink signal comprises subband

4   signals, comprising:

5   grouping the uplink signals into a plurality of groups, the number of groups at least

6   equal to a number of cell-reuse patterns of the cell-based transmission matrix, each group

7   comprising a signal from each frequency used in the frequency reuse pattern;

8   separating each group of uplink signals into subband signals;

9   grouping similar subband signals from the groups of uplink signals to produce

10   groups of similar subband signals; and

11   forwarding the groups of similar subband signals to demodulators for processing

12   within the satellite system.

1   12.   The method of Claim 11, wherein the uplink signals comprise signals of

2   different polarizations.

SWITCH MATRIX FOR SATELLITE PAYLOADS WITH MULTIPLE UPLINK BEAMS AND ON-BOARD SIGNAL PROCESSING

ABSTRACT OF THE DISCLOSURE

A method and apparatus for switching signals through a switch matrix are

5   disclosed. The apparatus comprises an input module and an output module. The input

module has a plurality of inputs typically equal to a number of cells in a reuse pattern, and

the inputs receiving at least one uplink beam. The input module also has a plurality of

outputs, the plurality of outputs is typically equal to the number of subbands in the uplink

beam. The output module is coupled to the input module and selectively couples the

10   outputs from the input module to an output of the output module. The method comprises

the steps of grouping the uplink signals into a plurality of groups, the number of groups

typically equal to a number of cells in the cell-based transmission matrix, where each group

comprises a signal from each frequency used in the frequency reuse pattern. Each group of

uplink signals is then separated into subband signals, which are then grouped together into

15   groups of similar subband signals. The groups of similar subband signals are then

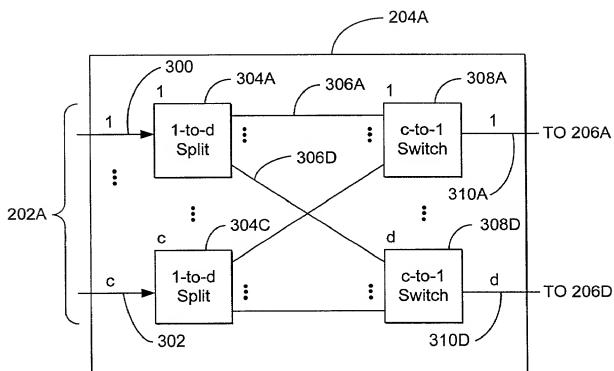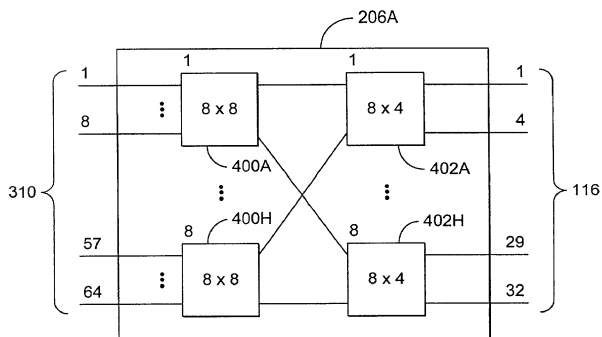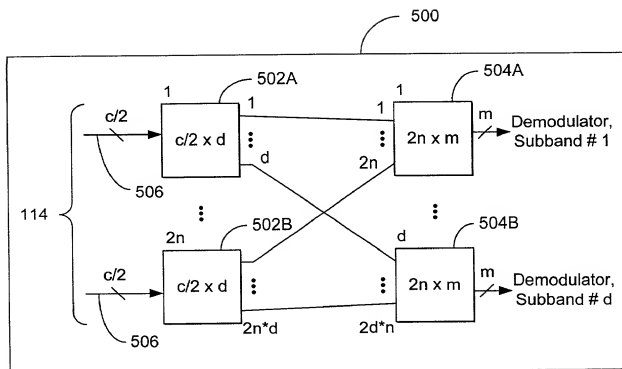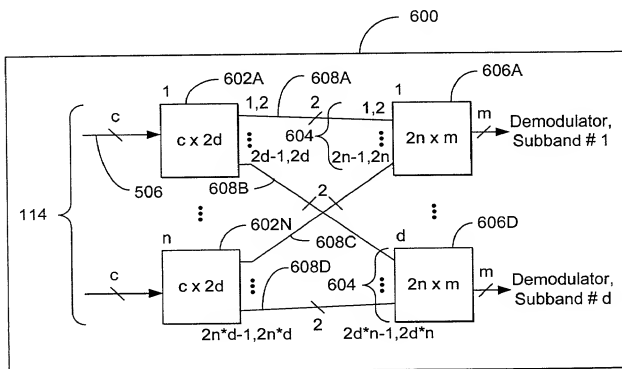forwarded to demodulators for processing within the satellite system.
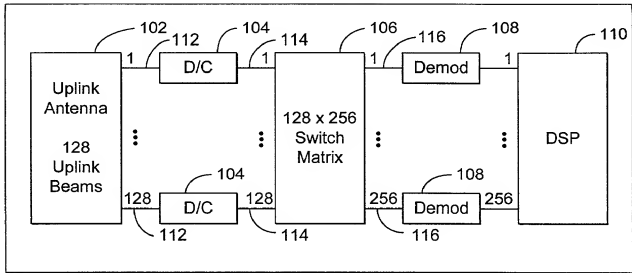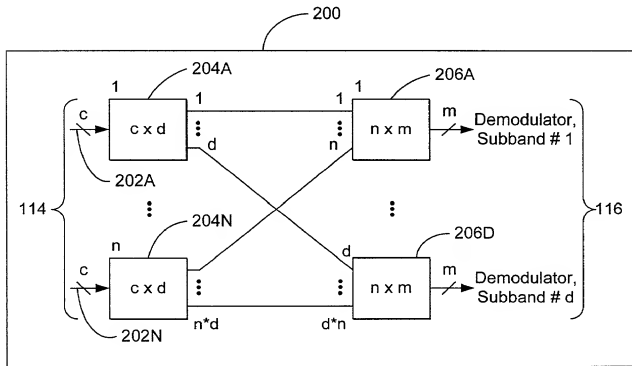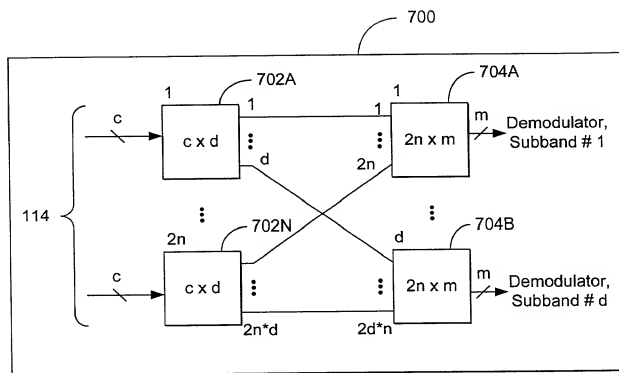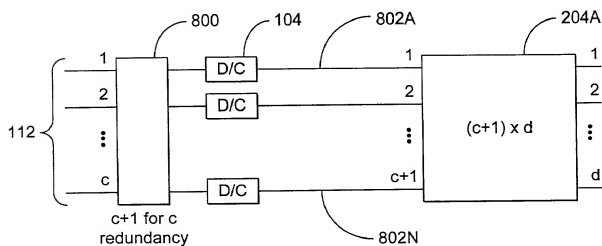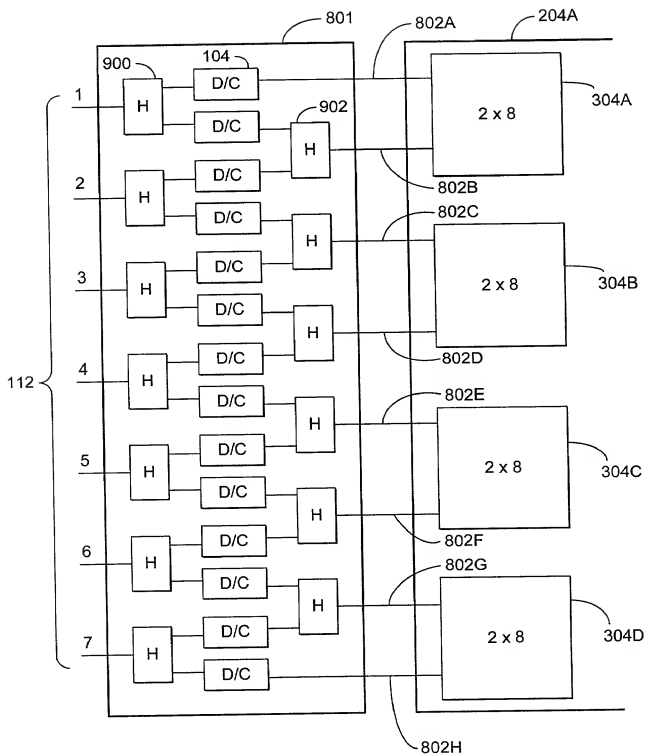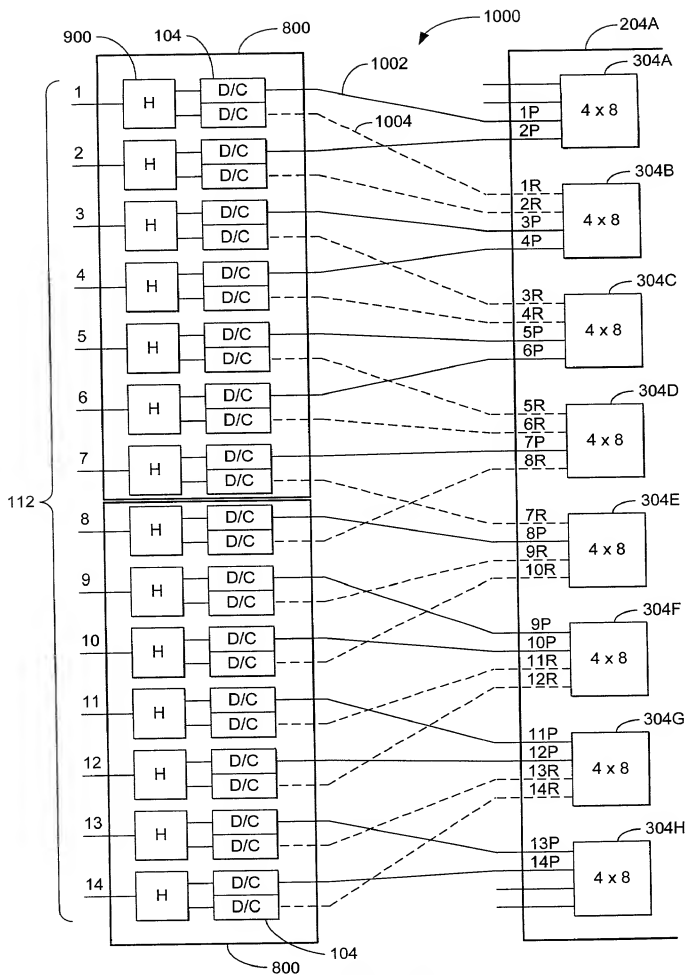
FIG. 1

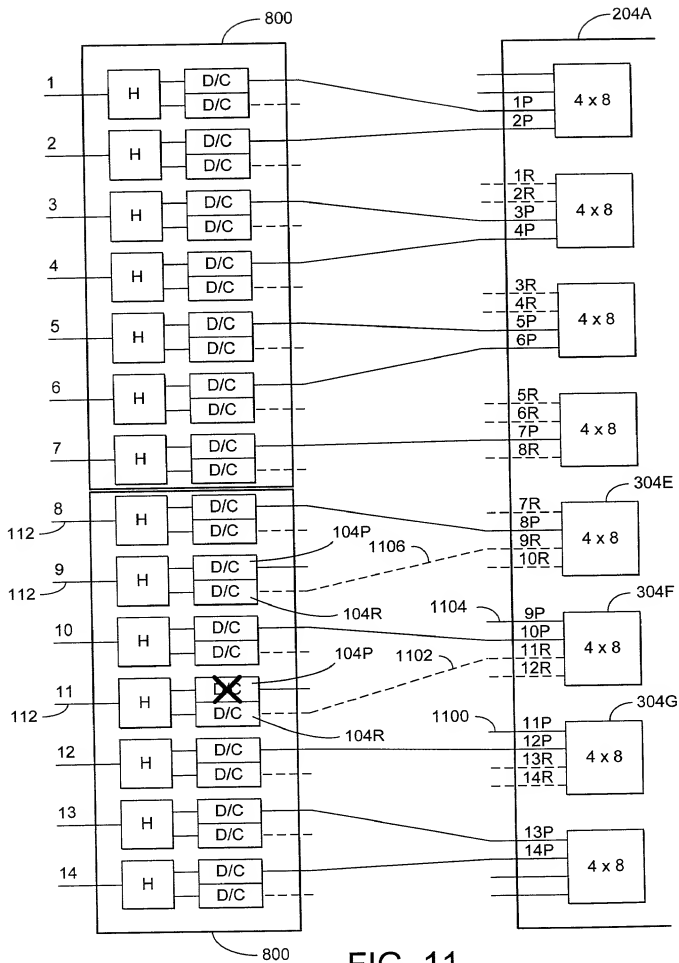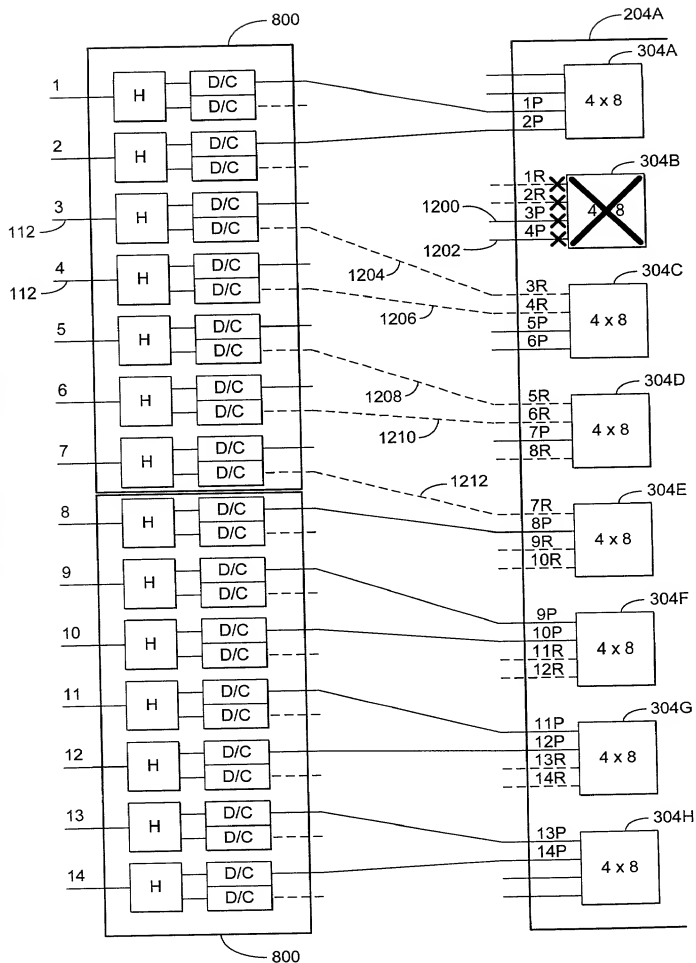FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6

FIG. 7

FIG. 8

FIG. 9

FIG. 10

FIG. 11

FIG. 12

FIG. 13

FIG. 14A

FIG. 14B

1500

GROUP THE UPLINK SIGNALS INTO A
PLURALITY OF GROUPS, THE NUMBER OF
GROUPS AT LEAST EQUAL TO A NUMBER OF
CELLS IN A FREQUENCY REUSE PATTERN OF
THE CELL-BASED TRANSMISSION MATRIX,
EACH GROUP COMPRISING A SIGNAL FROM
EACH FREQUENCY USED IN THE FREQUENCY
REUSE PATTERN

1502

SEPARATE EACH GROUP OF UPLINK SIGNALS
INTO SUBBAND SIGNALS

1504

GROUP SIMILAR SUBBAND SIGNALS FROM THE
GROUPS OF UPLINK SIGNALS TO PRODUCE
GROUPS OF SIMILAR SUBBAND SIGNALS

1506

FORWARD THE GROUPS OF SIMILAR SUBBAND
SIGNALS TO DEMODULATORS FOR
PROCESSING WITHIN THE SATELLITE SYSTEM

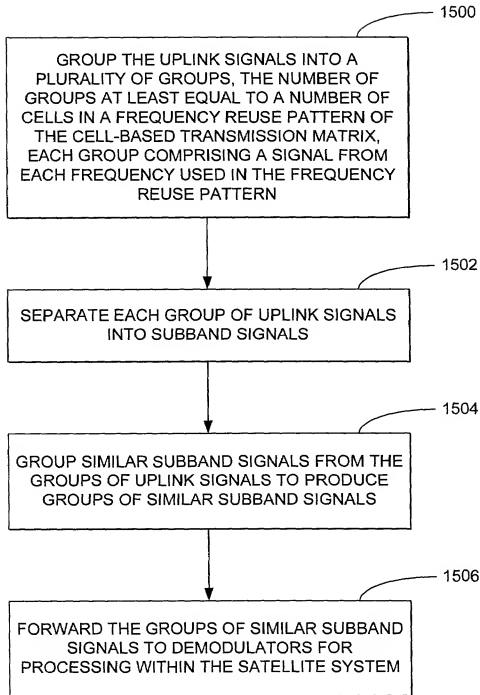FIG. 15

HUGHES

COMBINED DECLARATION FOR PATENT APPLICATION
AND POWER OF ATTORNEY

☑ Original
☐ Continuation
☐ Division
☐ Continuation-in-part
☐ Supplemental

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **SWITCH MATRIX FOR SATELLITE PAYLOADS WITH MULTIPLE UPLINK BEAMS AND ON-BOARD SIGNAL PROCESSING** the specification of which

(check one)   ☑   is attached hereto.

☐   was filed on _____ as Application Serial No. _____ and (a) [other than supplemental] was amended on or (b) [supplemental] with amendments through _____.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed
☐ Yes   ☑ No

Number	Country	Day/Month/Year Filed

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Filing Date	Status (patented, pending, abandoned

I hereby appoint the following attorneys, or agent and attorneys, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Terje Gudmestad   Registration No. 32,232;   Vijayalakshmi. D. Duraiswamy, Registration No. 31,505
Michael W. Sales   Registration No. 30,213
Wanda K. Denson-Low Registration No. 32,215

Address all telephone calls to **Terje Gudmestad, (310) 662-8915,**

Address all correspondence to **Customer Number 020991 (Hughes Electronics Corporation, Patent Docket Administration**, Bldg. 001, M/S A109, PO Box 956, El Segundo, California 90245-0956).

I hereby declare that all statement made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such false statements may jeopardize the validity of the application or any patent issued thereon.

FULL NAME OF SOLE OR JOINT INVENTOR Peter John Turley	INVENTOR'S SIGNATURE	DATE 3/21/00
RESIDENCE (CITY AND STATE) 2112 Warfield Avenue, #8, Redondo Beach, California 90278		CITIZENSHIP USA
POST OFFICE ADDRESS 2112 Warfield Avenue, #8, Redondo Beach, California 90278		
FULL NAME OF SOLE OR JOINT INVENTOR Shih-Chang Wu	INVENTOR'S SIGNATURE	DATE 3/24/00
RESIDENCE (CITY AND STATE) 2333 Hitchcock Drive, Alhambra, California 91803		CITIZENSHIP USA Taiwan
POST OFFICE ADDRESS 2333 Hitchcock Drive, Alhambra, California 91803		